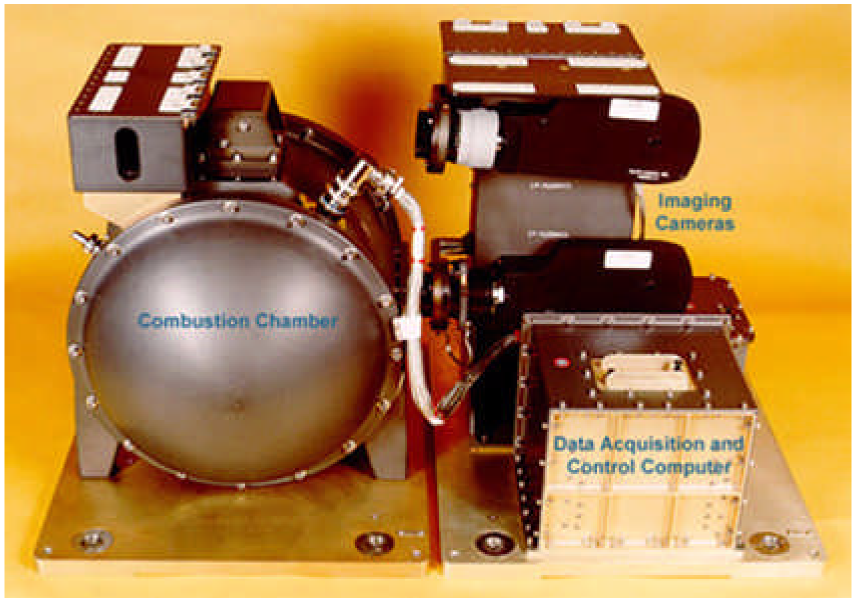
Solid Surface Combustion Experiment Yields Significant Observations

The spread of a flame over solid fuel is not only a fundamental textbook combustion phenomenon, but also the central element of destructive fires that cause tragic loss of life and property each year. Throughout history, practical measures to prevent and fight fires have been developed, but these have often been based on lessons learned in a costly fire. Since the 1960's, scientists and engineers have employed powerful tools of scientific research to understand the details of flame spread and how a material can be rendered nonflammable. High-speed computers have enabled complex flame simulations, whereasand lasers have provided measurements of the chemical composition, temperature, and air velocities inside flames. The microgravity environment has emerged as the third great tool for these studies.

Spreading flames are complex combinations of chemical reactions and several physical processes including the transport of oxygen and fuel vapor to the flame and the transfer of heat from the flame to fresh fuel and to the surroundings. Depending on its speed, air motion in the vicinity of the flame can affect the flame in substantially different ways. For example, consider the difference between blowing on a campfire and blowing out a match. On Earth, gravity induces air motion because of buoyancy (the familiar rising hot gases); this process cannot be controlled experimentally. For theoreticians, buoyant air motion complicates the problem modeling of flame spread beyond the capacity of modern computers to simulate. The microgravity environment provides experimental control of air motion near spreading flames, with results that can be compared with detailed theory.

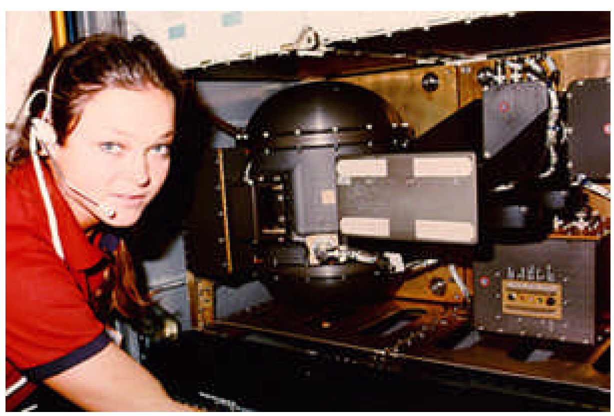
The Solid Surface Combustion Experiment (SSCE) was designed to obtain benchmark flame spreading data in quiescent test atmospheres--the limiting case of flames spreading. Professor Robert Altenkirch, Vice President for Research at Mississippi State University, proposed the experiment concept, and the NASA Lewis Research Center designed, built, and tested the SSCE hardware. It was the first microgravity science experiment built by Lewis for the space shuttle and the first combustion science experiment flown in space.



Solid Surface Combustion Experiment hardware, including the chamber module and camera module.

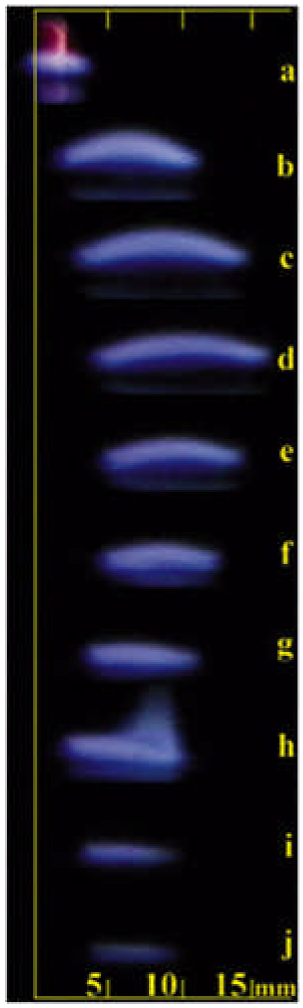
Hardware for SSCE consisted of a sealed chamber module containing the test samples, ashless filter paper or polymethylmethacrylate (PMMA, an acrylic plastic), and a test atmosphere of 35- to 70-percent oxygen mixed with nitrogen. The samples were instrumented with thermocouples. A second module contained cameras, a computer, and a battery.

SSCE has flown 10 times on the space shuttle, with the final flight, STS-91, occurring during 1998. In each experiment, the samples ignited successfully. The resulting flames were recorded on film and video; thermocouple temperatures were recorded digitally.



Astronaut Tamara Jernigan performing the Solid Surface Combustion Experiment in the Space Shuttle Columbia during STS-40.

Several scientifically significant observations have emerged from the SSCE tests. Steady flame spread occurs over thin samples, even in quiescent atmospheres. Thicker PMMA samples burn unsteadily and finally self-extinguish, but they require as long as 9 min (e.g., the STS-85 test) to quench. Comparisons of flight data with Professor Altenkirch's numerical simulations indicate that (unlike in normal gravity) radiative heat transfer is a dominating influence in flame spread in quiescent atmospheres. In summary, these experiments demonstrate that the controlling mechanisms for material flammability and flame spread are quite different in microgravity and normal Earth gravity. Results of the SSCE experiment will help spacecraft designers and Earth-bound fire safety technologists to improve fire safety, through enhanced fire prevention, detection, and mitigation techniques.



Side-view image of unsteady flame spread over a flat sample of PMMA in a test atmosphere of 50-percent oxygen/50-percent nitrogen at 1 atm of pressure. The flame advanced nearly 2 cm from the ignitor, then regressed and finally extinguished, requiring nearly 9 min to quench.

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